never set up a battery. The young astronomer sees the stars and planets themselves through the telescope. So do serious students of biology or medicine see for themselves the structure of the body, see for themselves the workings of that structure through the experiments of the physiological or pathological laboratory or lecture room, just as medical students, they see disease in the wards of hospitals, and look on or assist at the surgical operations performed upon men, women and children. No models and pictures can replace such teaching. From this last fact there is no escape. It is rooted in the constitution of the human mind. No mother would knowingly allow her childern to ride behind a locomotive engineer who had never seen the workings of an actual engine. Surely the physician who does his best to guide the living mechanism along the path of safety should be taught its natural workings as exactly and as fully as possible; otherwise he may understand its working in disease.

Happily the cases where the animals seen at demonstrations must undergo more than brief or trival pain are even rarer than in cases of pure research. In the very great majority of demonstrations the creatures can be kept free of pain until they are killed. As to whether or no, under given circumstances of research or teaching, an experiment involving pain should be performed, is a matter which should rest with the responsible expert, by whom or under whose direction the thing would be done. Otherwise, in a matter involving the interest of the community, those who know would be directed by those who do not know. For any experiment improperly conducted the person responsible is liable under the general laws against the maltreatment of animals. In fact, American biologists and physicians are no more inclined than other members of the community to culpable negligence toward their fellow-creatures. The work of science goes on; but those who are responsible desire, and see to it, that the work be painless, so far as admissible. No intelligent man or woman should give heed to the denunciations of those few ill-informed or headstrong persons who have been drawn into one of the less wise of the agitations which beset modern society.

Signed: S. Weir Mitchell, J. G. Curtis, W. H. Howell, H. P. Bowditch, W. T. Porter, J. W. Warren, R. H. Chittenden, V. C. Vaughan, John Marshall, S. B. Ward, William Pepper, S. C. Busey, Henry M. Lyman, E. G. Janeway, Ch. Wardell Stiles, William Patten, William T. Sedgwick, H. C. Ernst, Theobald Smith, A. C. Abbott, J. J. Abel, A. R. Cushny, H. C. Wood, Frank Baker, Harrison Allen, G. A. Piersol, C. S. Minot, Henry F. Osborn, C. O. Whitman, William H. Welch, T. M. Prudden, R. H. Fitz, George M. Sternberg, J. Rufus Tryon, Walter J. Wyman, Daniel E. Salmon, G. Brown Goode, W. W. Keen, William Osler, J. Collins Warren, W. T. Councilman.

CERTITUDES AND ILLUSIONS: AN ILLUSION CONCERNING REST.

Twenty centuries of investigation have dispelled many illusions. In examining the folklore of the world it is found that the lower the stage of culture the greater the number of these illusions. Since systematic researches were inaugurated by the Greeks many have been explained, yet some remain, even in the scientific world of today. On the threshold of our work it becomes necessary to dispel an illusion developed by primordial men and handed down through sequent generations to the present time, so that even now there are few minds unclouded by its mystic presence. When the ball is in the hand it seems to be at rest; when it flies from the hand motion seems to be created; and when it stops upon the

ground motion seems to be destroyed. When the horse stands he seems to be at rest; when he moves motion seems to be created; and when he stops motion seems to be destroyed. The ship is idle in the harbor, and it seems to rest or to be without motion; the winds fill its sail, and it seems that motion is created; it is becalmed at sea and the motion seems to be destroyed. Without the consideration of other unseen facts, rest seems to be a state without motion, and it appears that motion can be created and destroyed. This is the illusion to be dispelled. It is proposed to demonstrate that acceleration in molar motion is deflection of molecular motion, and in general that acceleration in any body is deflection in the particles of the body.

For this purpose it becomes necessary to define what is here meant by the terms body and particle. The universe is discovered to be a hierarchy of bodies. The solar system is a group of stars. When the solar system is considered as a unity the particles of which it is composed are the stars, but when one of these is studied as a unity it is found to be composed of particles. When any one of these particles is considered by itself it is a body. A molecule is a body considered as a molecule, but it is composed of many atoms, which are its particles. If, on the other hand, the atoms are compound, then they are bodies. Thus it is that a body is composed of particles, and that which is a body or system in relation to its component particles may be a particle in relation to a body or system of a higher order. It is in this sense that the term must be understood when we affirm that acceleration in a body or system is deflection of its particles. The ball in the hand is not at rest, or without motion in its particles; the horse has not more motion in its particles when running than when standing; the ship at anchor has motion still in its particles. These propositions are all simple and can be easily demonstrated, and yet the illusion remains. These seeming paradoxes are to be explained if we affirm that motion cannot be created or destroyed.

It has been demonstrated by science that motion is persistent—cannot be created or annihilated, and the demonstration has been accepted by a great body of scientific men. Antecedent to this demonstration Newton had propounded three laws of motion, one of which is that action and reaction are equal and in opposite directions. In this axiom the persistence of motion or the indestructibility of energy was implied, but at first its full significance was not understood, perhaps not even by Newton himself.

In 'The Principia' his first chapter is a series of definitions, the third of which is as follows:

"The *vis insita*, or innate force of matter, is a power or resisting by which every body, as much as in it lies, endeavors to persevere in its present state, whether it be of rest or of moving uniformly forward in a right line.

"This force is ever proportional to the body whose force it is, and differs nothing from the inactivity of the mass, but in our manner of conceiving it. A body, from the inactivity of matter, is not without difficulty put out of its state of rest or motion. Upon which account this *vis insita* may, by a most significant name, be called *vis inertiæ*, or force of inactivity. But a body exerts this force only when another force impressed upon it endeavors to change its condition, and the exercise of this force may be considered both as resistance and impulse; it is resistance, in so far as the body for maintaining its present state withstands the force impressed; it is impulse, in so far as the body, by not easily giving way to the impressed force of another, endeavors to change the state of that other. Resistance is usually ascribed to bodies at rest, and impulse to those in motion; but motion and rest as commonly conceived

are only relatively distinguished, *nor are those bodies always truly at rest which commonly are taken to be so.*"

In the last sentence quoted it is apparent that Newton himself was conscious of an illusion in the common conception of the term rest, and it is plain from his entire discussion that his term inertia stood for real force, although many scholars since his time have denied this proposition. Had Newton discovered the real nature of what he called *vis inertiæ* 'The Principia' would have been simplified, as it has been since his time, by definitions given to momentum, energy, force and power. But even these newer definitions can be revised and the subject presented in a simpler manner. The purpose in view in this chapter is to re-define *vis inertiæ*, and to explain the phenomenon of rest in molar bodies by showing that it is not annihilation of motion, but change in the direction of motion, and that the ordinary concept of rest in molar bodies is an illusion, and that this illusion has been carried into the realms of molecular and stellar motions.

Vis inertiæ or inertia is a component of real force, inherent in every particle of matter as speed of motion, which can be changed in direction only through the agency of collision. The explanation of Newton's third law of motion in this manner changes the ideas of motion as they have heretofore existed in philosophy. Motion as speed is inherent, and not something imposed from without. If indeed, this be true, then much reasoning in scientific circles must be revised, for it has far-reaching results.

The correlation of forces through the persistence of motion or the persistence of energy is not universally accepted, but is widely accepted, and it seems to be growing in favor by reason of its great simplicity, and because it furnishes an explanation of many facts and a conceivable explanation for many more, but chiefly from the all-important consideration, attested again and again by observation, that motion is a real cause or antecedent of force and that no other cause is known. A second explanation of force is never even propounded except as a reification of abstractions inherited from the age of metaphysics, and still found as an atavism in science.

In the consideration of motion it is necessary to consider the two elements, namely, speed and direction, or path, for each term posits the other. The persistence of motion inheres in the element of speed. While the body in motion must have a path its direction is variable, *i. e.*, not persistent as a right line. It must therefore be understood that in speaking of the persistence of motion it is the element of speed to which reference is made. To affirm that motion is persistent is equivalent to the affirmation that speed is persistent, though the path of motion may change. It is not proposed here to discuss the conservation of energy nor the kinetic hypothesis that force is the collision of matter in motion, but to assume these theories for the purpose of exhibiting their logical consequences.

In every collision of one particle or body with another there is a double correlative involved. When A and B collide, A acts on B and B on A, so that there is both action and passion in A and B which are coexistent. Then we have to consider A before the collision and A after the collision, and B before the collision and B after the collision. There is thus a double cause and a double effect which are sequent. The matter may be expressed in another way. A and B coöperate in producing effects on each other. In this coöperation action and reaction are involved. The action is the cause and the reaction is the effect. How is the cause quantitatively related to the effect and how is the effect divided between them? It is proposed to prove that collision does

not produce any change in the speed of A or B, but the result of the collision is the deflection of the paths of both and this deflection is proportional to their masses. All this is simple in the collision of two free bodies of a certain class, both of which are in motion and which collide when their paths impinge upon each other. But two bodies, A and B impinge. A is without molar motion; B has molor motion. Will B yield a part of its motion to A, or will B retain its motion as in the case of two free moving bodies and create motion in A? Or if A is unmoved and B is stopped in its molar motion will motion be annihilated? If two molar bodies are free and both in motion and their paths impinge, neither particle has its speed increased or diminished, but if one is at rest it will be put in molar motion and it will thus appear to have motion given to it either by the creation of motion or by taking it from the other. The illusion involved arises from this, that the molar body said to be at rest is really not at rest. If they are both free and in motion it is plain that one does not yield motion to the other. But if one of the bodies is in the state called rest it appears that it is set in motion or that the other body is brought to rest. In the first case it seems that motion is not created nor annihilated, in the second that motion is created and in the third that motion is annihilated. Is this true? This is the question we are to answer. Can motion in any body be created or destroyed by collision? It appears so, but we are to show that this appearance is an illusion.

Every particle of matter known to man is in motion at a high velocity. This wooden ball is in motion about the axis of the earth, about the sun, and also with the sun about some other point in the heavens. The sum of all these motions considered as speed is unknown, but it may be affirmed with safety that it is very great. Let us call this the telluric motion of the ball, its motion with the earth. Its path is composed of at least three contemporaneous revolutions. However great the speed of the telluric motion, it is yet small as compared with other motions within the body itself. As now understood the woody tissue is composed of cells, the cells of molecules, and the molecules of atoms, all grouped in such a manner by composed motion as to constitute a tissue whose structure is preserved by molecular motion. That rigidity is sometimes due to motion is well known. Stand by the nozzle of a monitor with four hundred feet of pressure behind the water and watch the stream drive the great boulder away. Strike this stream with a crowbar; though the iron may bend, the stream is unbroken. So we may conceive that rigidity and strength of structure are properties of motion. Let us call this rigidity and structural strength of the woody tissue constitutional motion, whose force is equal to the sum necessary to rend the ball into its constituent atoms. The structural strength is a measure of its constitutional motion, which is great as compared with any molar motion observed in the ball. Again the body exhibits a mode of motion known as heat, which is undulatory or vibratory. Of the speed of radiant heat something is known, and it is well-known that it is very great as compared with any molar motion observed in the bodies which exhibit the heat. Let us call this constitutional and thermic motion molecular motion.

I roll the ball over the floor, and molar motion is exhibited to the vision.

Thus we know of three kinds of motion possessed by the body, but that which is apparent to the unaided vision as molar motion is but a minute part of the whole. It is evident that it is a very small part of the telluric motion. Let us now see what proportion it bears to the molecular or the constitutional and thermic motions com-

bined. The constitutional motion is measured by the force with which the atoms, molecules and cells are held together as an organic body. If we attempt to realize this we find it very great, yet we cannot attain to its measure, from the fact that it is complicated with the heat motion of the body, but we can obtain some realization of the sum of the two kinds of motion, though we cannot with certainty divide the molecular motion between them.

Let us first consider the velocity of reasonably well-known molecular motion:

VELOCITY OF GAS MOLECULES.

	Meters per second.
Atmospheric air	485
Oxygen	425 to 458
Nitrogen	453 to 491
Hydrogen	1838 to 1841
Ammonia	628 to 737
Aqueous vapor	614

VELOCITY OF THE TRANSMISSION OF SOUND.

	Meters per second.
In air	333
" oxygen	317
" hydrogen	1270
" ammonia	415
" water	1435

But all of these same molecules have the motion of the earth, first about its axis, which at the equator is 465 meters per second, and in orbit 29,606 meters per second. Neglecting the motion of the earth with the sun about some other point in the heavens we still see that the known molecular motion, plus the known telluric motion, which we have considered, far exceeds any molar motion observed in nature or produced in art. The molecular motion of a cannon ball at its mouth is from 518 to 671 meters per second. In telluric motion we have the motion of bodies, and again in molecular motion we have the motion of bodies. The molecules themselves are compound, and in order that the molecular bodies themselves should retain their constitution it is necessary that the motion of their particles should be made immensely composite as correlative motions. What idea can we obtain of the velocity of this particle motion? Take the wooden ball which we have considered and burn it and we have motion as light, and light is transmitted at the rate of 299,878,000 meters per second. Here we have particle motion at a velocity so great that any observed molecular motion sinks into insignificance; all of the ethereal motions seem to be at least of rudely commensurate magnitude. If the atoms are compound, as seems to be indicated by a large body of evidence obtained through chemical research, possibly it may be that the particles of atoms are commensurate with the particles of ether and that they have the same speed; but this hypothesis is not necessary to the present argument. It is only necessary to show that the molecular and constitutional motions, together with the telluric motions of every particle, are of such a magnitude as to fall far within the speed of molar motion.

None of these motions are persistently right-line motions. It is manifest that the stellar motions are great revolutions. The constitutional motions are also enormously composite. The heat motions, though they may be right-line motions in minute parts, must be composite motions, their paths forever changing, else the body would be dissipated. The particle motion of each particle in the molecule has its path confined to the sphere of the molecule itself. Considering this motion, both structural and thermic, not in relation to telluric motion nor in relation to molar motion, but wholly in relation to the particles of the molecule, it must be highly composite. The molar motion of the rolling ball is revolution and translation, but it is so small as compared with the others that it hardly seems worthy of consideration. Still it must not be neglected, for this is the motion the characteristics of which we have set out

to explain. Let us once more consider what has been said. The atoms of the ball, when all their motions are analyzed and summed, prove to have enormous velocities in enormously composite paths compared with which the molar motion of the ball on the floor sinks into insignificance.

Every particle in the wooden ball rolling on the floor has telluric motion, molecular motion and molar motion. Consider one of these particles moving with the three kinds of motion, and we realize that its speed is very great and that the path which it traverses is greatly composite. If such a particle had its composite path straightened into a right-line path it would at once pass out of the sphere of the solar system into a region beyond, from whatever point within the system it might start, and in whatever direction the right-line path extended. But the molecule remains within the solar system because its stellar motion is composite; and it remains within the ball because its molar motion is composite; and it remains within the molecule because its molecular motion is complete.

When the ball was started molar motion began and when it stopped that molar motion ended. But we do not suppose that it came out for nothing and vanished into nothing; we resort to preëxisting molecular motion to explain it; we say that the molar motion was derived from the molecular motion of the hand that set the ball rolling and that it was transformed into molecular motion in the wall which destroyed the molar motion. In making this explanation we assume that motion as speed went out of the hand into the ball and then out of the ball into the wall. Is this true? Was the velocity of the molecular motion in the hand diminished and the velocity of the molecular motion in the wall increased? If so, action and reaction are not equal except in the sense that what is lost by one is gained by the other.

Did motion go out of the hand into the ball, or was the direction of motion existing in the ball changed? Did motion go out of the ball into the wall, or was the direction of motion existing in the wall changed? If the law of action and reaction is valid, when the change was made upon the ball by the hand, an equal change was made upon the hand by the ball. Neither of them lost velocity by the changed form, or one lost what the other gained. All of Newton's reasoning on this subject proceeds upon the assumption that the speed of each is unchanged, but that the direction of each is changed and that this deflection is equal in the case now considered. When the ball struck the wall neither ball nor wall lost motion, but the molecular paths were changed by collision. The form or mode of direction of motion was affected, the quantity of motion as speed was unaffected, if we follow Newton's reasoning. But there was a change in the hand, in the ball, and in the wall. In what did that change consist? We know that in part at least it consisted in a change of paths. The molecular motions in the hand must have had their directions changed; the molecular motions in the ball must have had their directions changed; in like manner the molecular motions of the wall were changed in direction. This we know; in every collision there is a change of direction in the motion of the particles constituting the bodies colliding. Is this change of direction all? Or is there a transference of speed so that one loses while another gains? The whole problem is narrowed to this issue—that which we call acceleration is wholly deflection or in part deflection and in part loss and gain—loss of speed by one and gain by another, and if there is any loss and gain then action and reaction are not equal, as Newton's law affirms.

There is still another set of relations which must be considered. A body is con-

stituted of particles; that the motion of the particles within the body should remain within the sphere of the body, their paths must be composite. In order that their paths may be composite there must be a sufficient number of collisions to deflect these several particles and retain them within that sphere.

If the body itself is moved the paths of the several particles in the average must thus be rendered less composite, that is, the number of collisions must be diminished. The motion of the body as such, therefore, is accomplished by diminishing the deflections within the body and straightening their paths. The translatory motion of a body is a straightening of the paths of the particles of which the body is composed.

Imagine a man walking in a circle of ten feet radius. The sphere of his motion is within the circumference. He may soon walk a mile and never be more than twenty feet away from any given point in the circumference; change his direction so that his path is straightened, and he may soon be a mile away. A body of men walking in a circle remain together as a body within the circumference of the circle as it moves with the earth; change their paths to a cycloid and the body of men will move away or change their paths to parallel right lines, and as a body they may soon be a mile away and still in a circle. In the same manner the molecules of the wooden ball are in motion within the theater of the ball, so that they do not pass beyond its boundaries, yet impose upon each molecule a change of direction in such manner that they all move a little more in one course and a translation of the ball is affected by a change of direction in the motion of its constituent molecules, and the ball still remains as an incorporated body. It is thus possible to explain molar motion of the ball as a change in direction of the motion of its molecular parts, without assuming an increase of speed in the parts. By such an assumption the molar motion perceived by vision would be legitimately derived from the molecular motion known by reason, and appear as a change of direction in the telluric motion of the ball.

No motion would be created or destroyed, and action and reaction would remain equal, while the apparent molar motion would be explained by a change of direction in molecular motions, very minute as compared with the composite paths of the several molecules and the composite path of the body in its telluric motion. When we consider the total motions of the atoms of the ball, even when it is shot from a cannon's mouth, an inconceivably small change of direction in the motion of every atom as compared with the complexity of its path would fully account for the flight of the ball as projected by dynamite.

Now we know of deflection and that it arises from collision, and we know of no other change in motion. Acceleration as increase of speed cannot in the nature of the case be demonstrated, for it may always be explained as deflection, and can never be explained without deflection; and to assume acceleration as increase of velocity is to contradict the law that action and reaction are equal and to affirm that motion can be created and destroyed.

If acceleration is explained as deflection, it is explained by referring it to a known cause and adequately explained.

Let this argument be stated in brief:

First, the tendency of modern investigation is to explain all forces as derived from modes of motion. Great progress has been made in this direction, and the theory is widely accepted.

Second, all understood forces are collisions.

Third, if all forces are collisions the motions from which they result obey the third law of motion, that action and reaction are equal. By this law it is seen that no mo-

tion as speed can be lost or gained by any particle of matter.

Fourth, by collision paths can be changed, but motion as speed cannot be transmitted.

Fifth, in molar motion there is an apparent creation and annihilation of motion, but this appearance is known to be an illusion. It has been explained as due in part to collision and in part to the transmission of motion. Acceleration, therefore, must be something else than an increase of speed. It is known to be in part deflection and can all be thus explained; and if the first law of motion is valid it is thus explained. Therefore:

1. Molar acceleration is deflection of molecules.

2. Speed of motion in matter is constant.

3. The direction of motion is variable.

4. Speed is inherent in matter and is not imposed upon it from without.

5. The path of motion is controlled by environment.

The laws of motion propounded by Newton can be more simply stated as follows:

Law I. The velocity of motion is persistent.

Law II. By the collision of two bodies the direction of their motions is changed in equal components.

Vis inertia is the power which particles have of deflecting each other by collision, due to their persistent motion.

Every particle has perpetual motion as speed which can not be increased or diminished, and the absurdity of perpetual motion should be called the absurdity of perpetual collision. The particles collide because of impinging paths; they are deflected and their paths are turned apart and they cannot be made to collide again until other external collisions bring their paths together. If the particle A after one collision is once more deflected, another collision is necessary. It is thus that the absurdity of perpetual collision can be simply demonstrated. After such an analysis the explanation of gravity as the mutual protection from impinging particles becomes simple, the doctrine of virtual velocities self evident; and there are many other consequences of this law which, properly understood, would make many propositions of physics self-evident.

It must be clearly understood that the above argument does not deny that the motion of a body cannot be accelerated in speed; such a denial would be an absurdity. Every particle of which we have knowledge is a constituent of many bodies in a hierarchy of bodies and what is here affirmed is that the acceleration of a body in speed is deflection of its particles, and that embodiment itself is always a result of deflection in the particles embodied. A molar body may have its molar motion increased or diminished in speed by deflecting its molecular motions. If the speed of a molar body be changed, the direction of its molecular particles must necessarily be changed. This proposition is self-evident. The third law of motion is equally simple. The law here demonstrated affirms that acceleration in one embodiment is deflection in another and it makes valid Newton's law, which would be an absurdity were the law here demonstrated untrue; and if untrue the persistence of motion is an absurdity, and with it the persistence of energy falls to the ground.

J. W. POWELL.

SCIENTIFIC NOTES AND NEWS.

ASTRONOMY.

THE *Astronomische Nachrichten* of February 22d contains an article by Dr. H. F. Zwiers, giving a new method of computing double-star orbits, and an application of it to the orbit of Sirius. The author does not claim great precision for his orbit of his star, and it is given simply as an illustration of his method of computation. We do not think, however, that the method will commend itself very greatly to astronomers. Glasenapp has pointed out (*Orbites*